A Quick First Look at the Impact of an LSND Oscillation Signal on the NOνA Near Detector

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Most assume that MiniBooNE will not confirm LSND oscillation signal

But what if they do? What are the implications for NOνA of a $\nu_\mu \to \nu_e$ oscillation with LSND-like parameters?

Consider 3 scenarios:

1. MiniBooNE confirms LSND
    a) What does this imply for our measurement of the beam ν_e content of the offaxis beam using the near detector?

    b) Can NOνA add anything to MiniBooNE's measurement?

2. MiniBooNE has an ambiguous result and cannot rule out LSND for all possible Δm^2 regions. Can NOνA add anything?

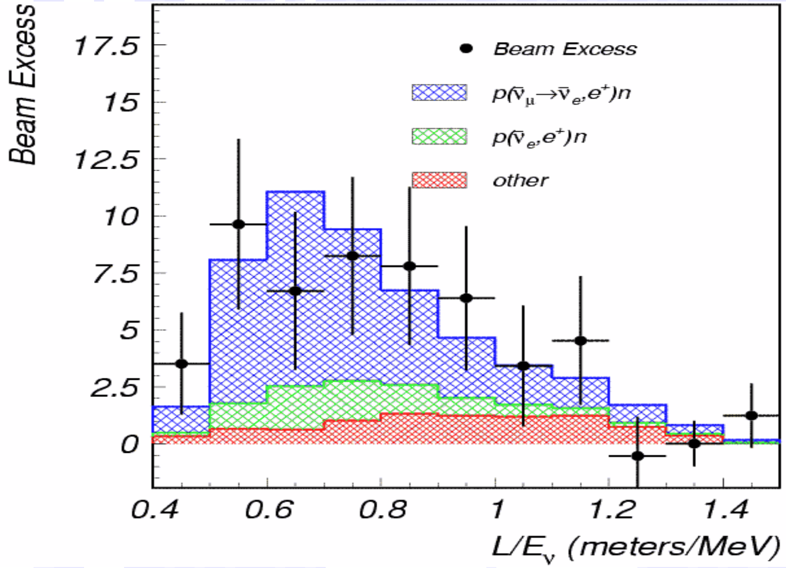
3. MiniBooNE sees no oscillation signal and moves onto antineutrinos. Can NOνA add anything with an offaxis antineutrino beam?

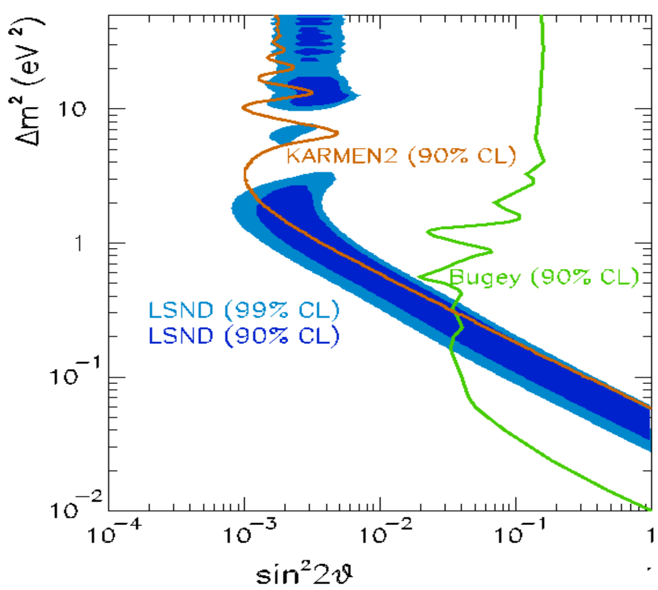
Review of LSND Result

88 event excess (4σ)

Interpreted as $\bar{\nu}_\mu \to \bar{\nu}_e$ oscillation with probability of 2.6×10^{-3}

LSND also reports a weaker result for $\nu_\mu \to \nu_e$ oscillation





The simplest oscillation model is given by

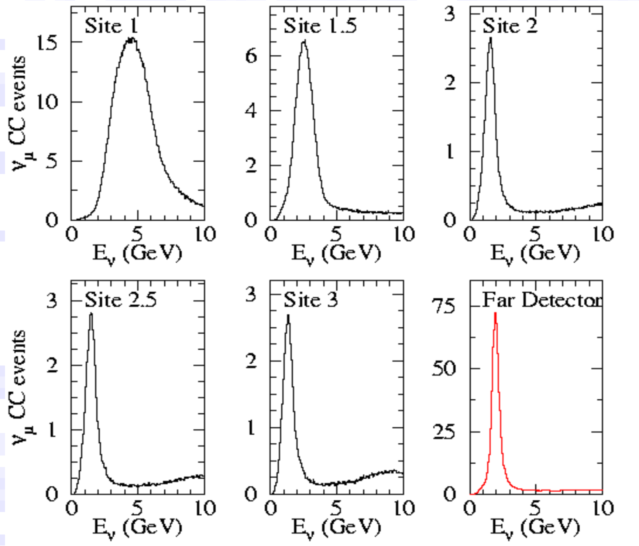
$$P_{ab} = \sin^2(2\theta_{ab})\sin^2(1.27(\Delta m^2)(L/E))$$

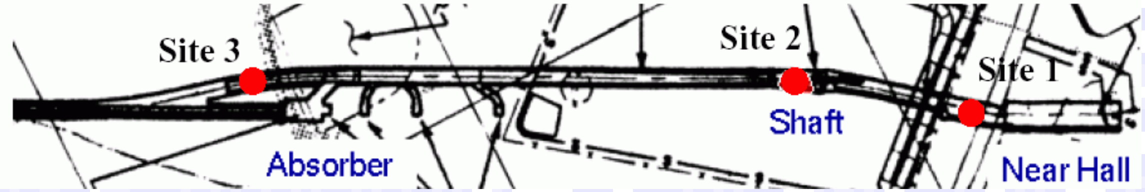
Possible Near Detector Sites

	Distance from Target (m)	Off-axis Angle (mR)*
Site1	1010	4
Site 1.5	975	11
Site 2	940	20
Site 2.5	840	22
Site 3	740	26

* Angle measured from ave. pion decay position, 200 m downstream of horn 1.

Mark's ν_μ Spectra

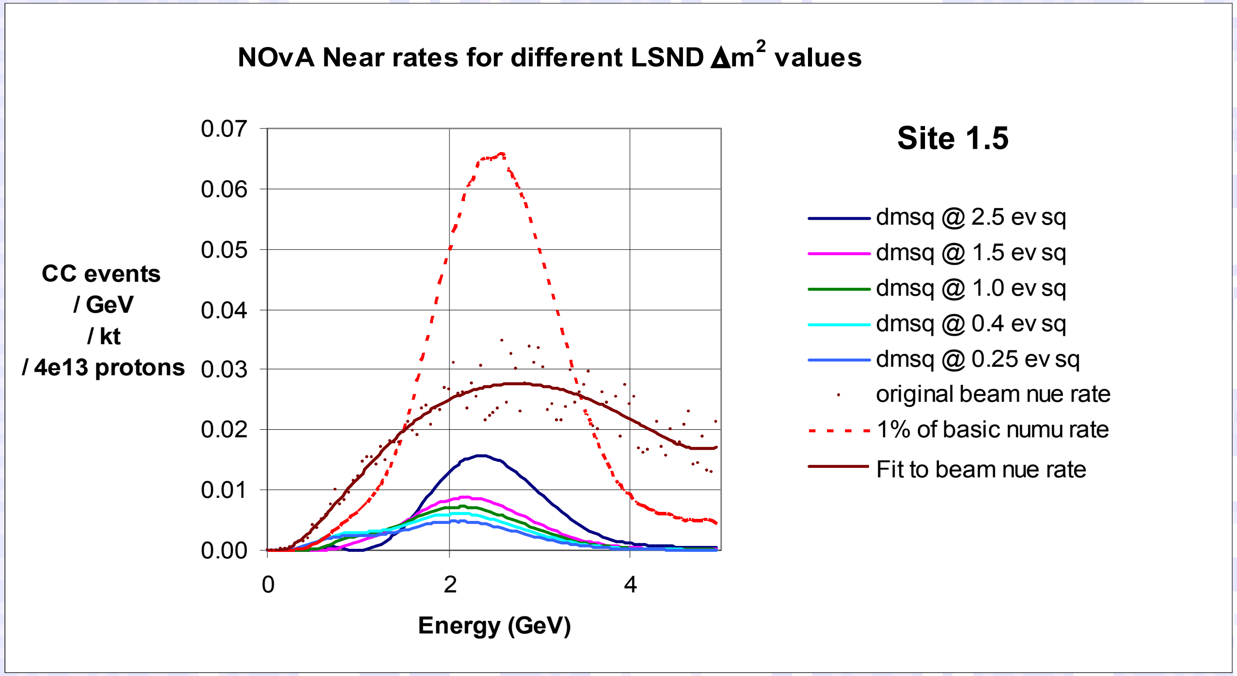


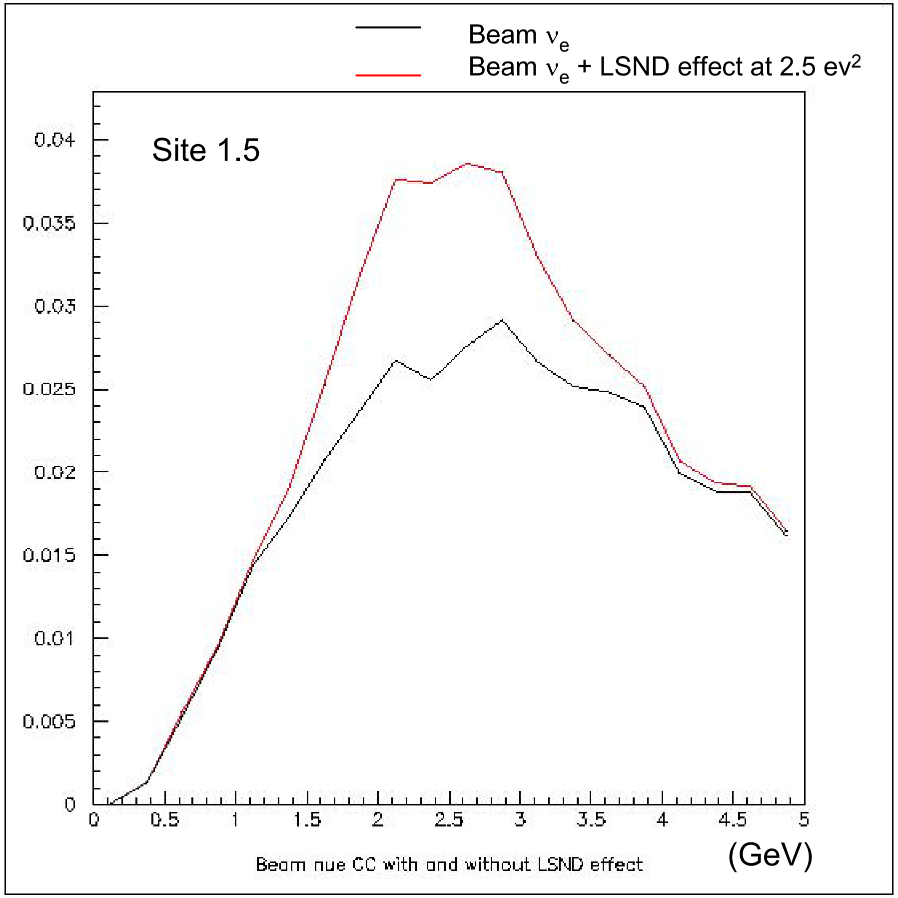


In our proposal we identify Site 1.5 as the best match to the ν_μ spectrum at the far site.

Scenario I(a) MiniBooNE Confirms LSND Result

We can see it too!





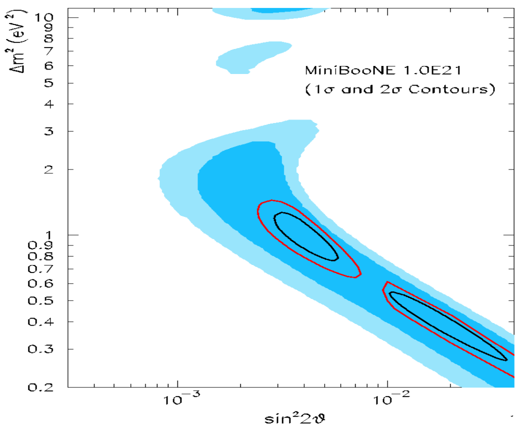
The effect can be sizable and observable by NOνA.

The significance of a NOνA observation depends on how well we know the beam ν_e spectrum and the NC contamination.

The purpose of the NOνA near detector is to measure the CC, NC and beam ν_e backgrounds and extrapolate them to the far detector. The LSND oscillation is another background that could appear in both the near and far detectors.

Scenario 1(b) MiniBooNE Confirms LSND. Can NOνA add anything?

MiniBooNE's expectation with 10^{21} p.o.t.



MiniBooNE's nest step would be a second detector at a more distant location. MiniBooNE currently sits ~0.5 km from their target.

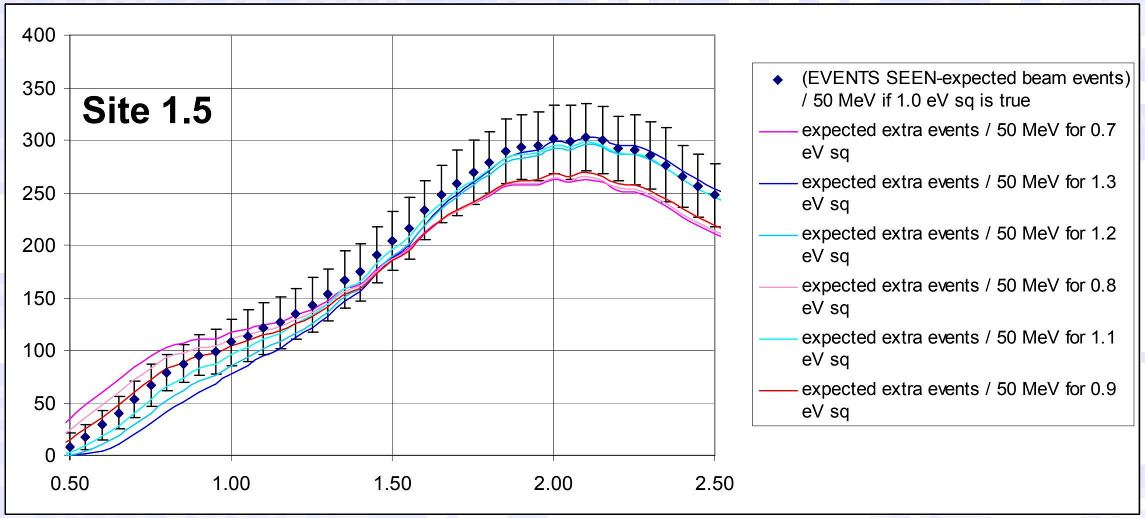
NOνA near detector will be 0.75 - 1.0 km from the NUMI target. The time scale for NOνA and a second MiniBooNE detector are similar.

80 NOνA tons might seem small compared to 445 MiniBooNE tons, but:

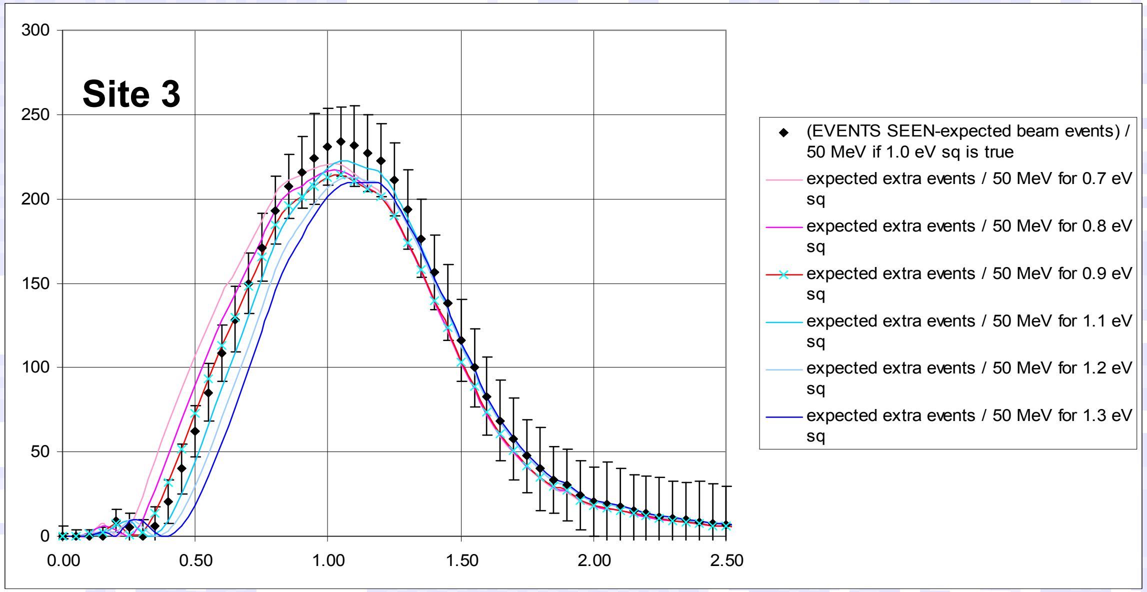
MiniBooNE - ~1 event/10^{15} p.o.t.
NOνA   ~23 events/10^{15} p.o.t. (results from higher ν cross section + more p.o.t/sec)

However, MiniBooNE is ideally located/designed to measure the LSND signal, NOνA is not…

Event numbers after subtraction of expected beam ν_e events for an 80 ton Near Detector after 4e20 protons (~ 1 year)



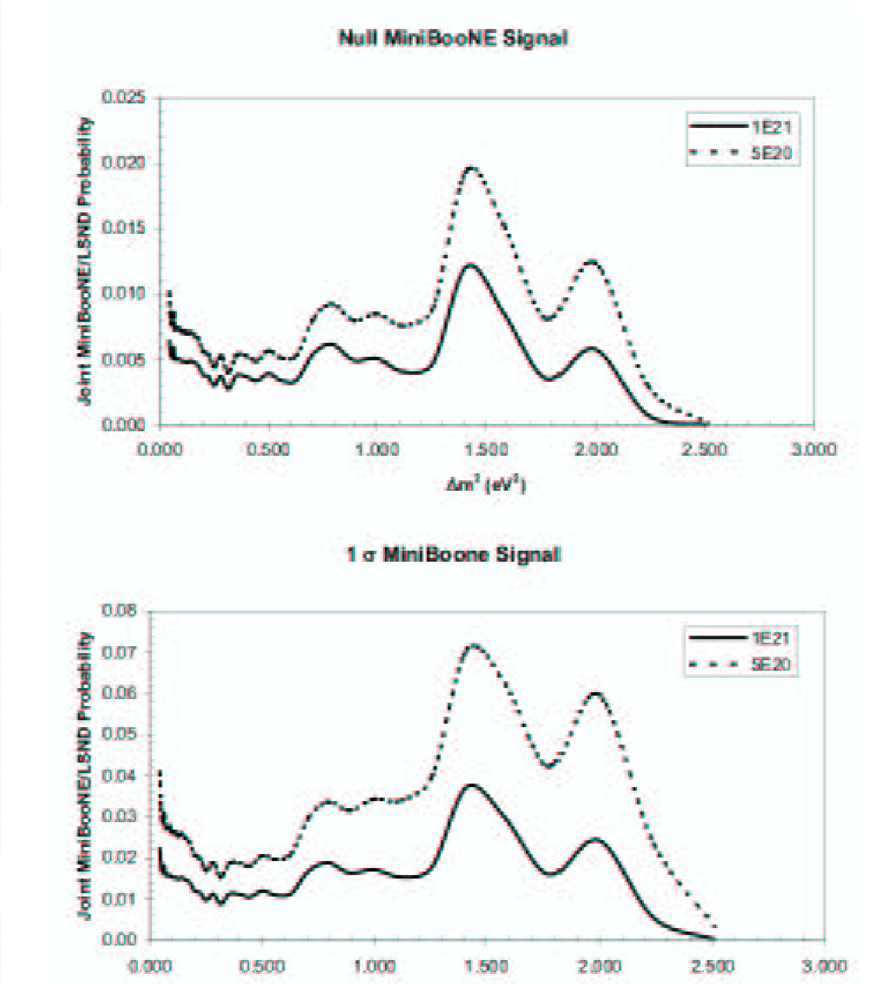
Error bars are based on the expected number of beam ν_e events



Pretty tough to differentiate.
Multiple near detectors?

Scenario 2 MiniBooNE has an Ambiguous Result

MiniBooNE can have a null result and still not completely rule out LSND



Joint probability analysis of a null MiniBooNE result and LSND positive result as a function of Δm^2. The bottom plot is for a 1σ upward fluctuation.

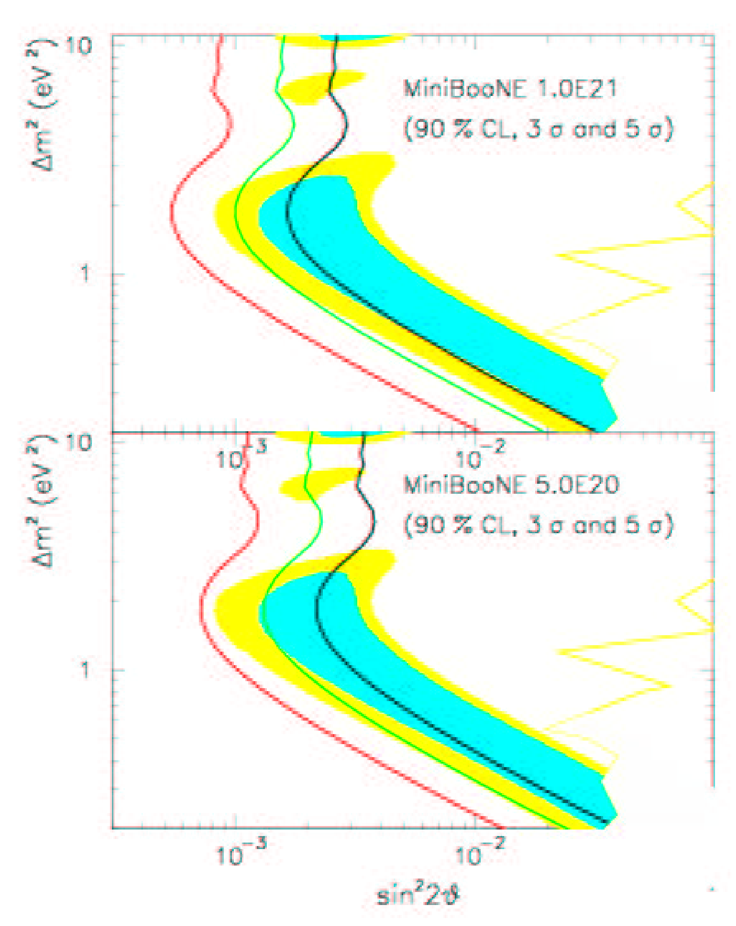
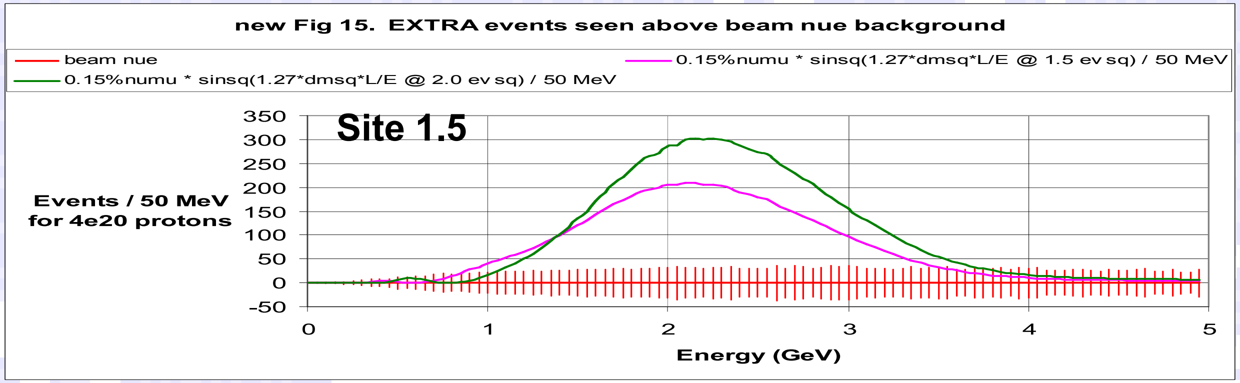
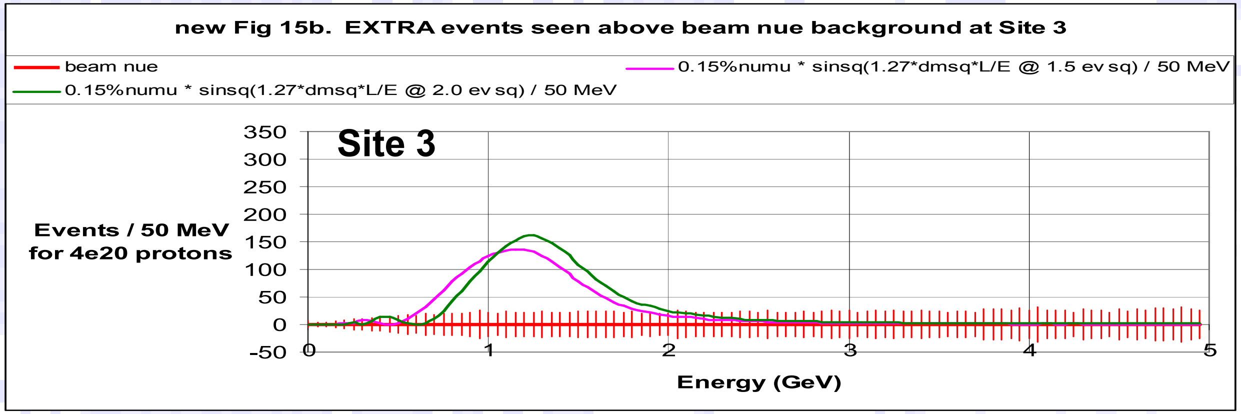
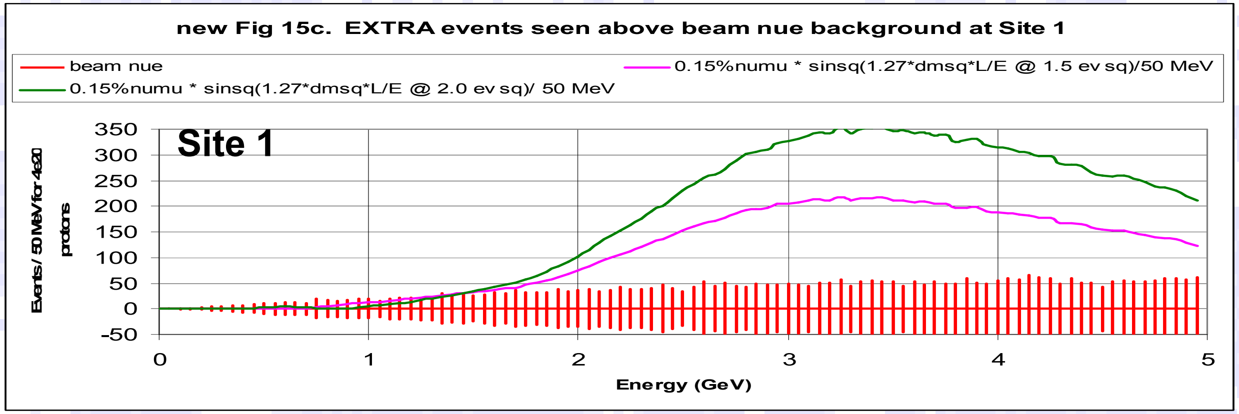


Figure 14. 1.6 σ (red), 3 σ (green), and 5 σ (black) exclusion curves for a MiniBooNE null result superimposed with the LSND 99% (yellow) and 90% CL allowed areas. The top plot is for 10^{21} pot and the bottom plot is for 5×10^{20} pot.







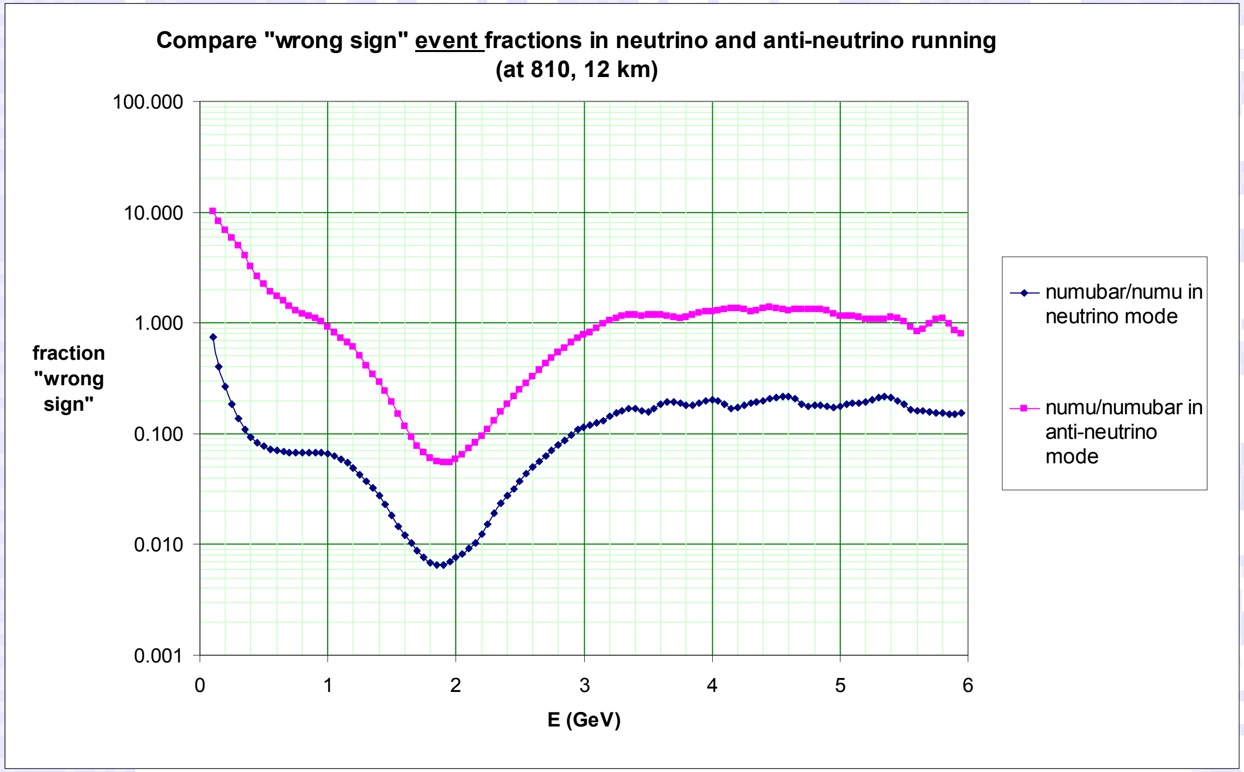
Again, we can easily see a significant effect or rule one out to some level of significance)

Differentiating between different Δm^2 values will be difficult.

Again, multiple near detectors could help.

Scenario 3 MiniBooNE Sees no neutrino result but continues to search with anti-neutrinos

- LSND observed their most significant excess with anti-neutrinos
- Some CP violation models predict larger oscillation probabilities for anti-neutrinos over neutrinos.
- APS Joint Study recommended running MiniBooNE with both ν and $\bar{\nu}$.
- MiniBooNE has ~30% wrong sign fraction in their anti-neutrino beam due to leading particle effects associated with using a proton beam.
- NUMI off-axis beam seems to be significantly better. Away from the energy peak the wrong sign fraction ~100%, but at the peak is only ~5%.
    - 2 horns instead of 1?
    - Different dynamics at 8 GeV and 120 GeV?
- Can we exploit this advantage in any way?



Compare "wrong sign" event fractions in neutrino and anti-neutrino running
(at 810, 12 km)
100.000
10.000
1.000
0.100
0.010
0.001
fraction "wrong sign"
0
1
2
3
4
5
6
E (GeV)
numubar/numu in neutrino mode
numu/numubar in anti-neutrino mode

Conclusions/Comments

NOνA cannot replace MiniBooNE. Instead, we are asking what impact an LSND oscillation might have on our core program and what additional information NOνA might supply on a comparable timescale.

For short baselines, using the average pion decay position to determine the baseline is not correct. This is particularly true for beam ν_e that can result from kaon decays. Initial studies where we change the baseline indicate a modest change in the shape of spectra, but the area under the curves does not seem to change.

Understanding the beam ν_e spectrum is important.

T2K has the same problem/opportunity. While NOνA has its greatest sensitivity at large Δm^2, T2K would likely be more sensitive at small Δm^2 because of their lower energy beam.